

FIFTH ANNUAL REPORT

OF THE

POWER AFFILIATES PROGRAM

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FOREWORD

This report is a summary of the activities of the Power Affiliates Program in the Department of Electrical Engineering at the University of Illinois for the calendar year 1983. The information is intended to be a progress report to the affiliate companies. These companies are:

Amoco Oil Company
Central Illinois Light Company
Central Illinois Public Service Company
Commonwealth Edison Company
Doerr Electric Corporation
General Electric Company
Illinois Power Company
Iowa-Illinois Gas and Electric Company
Northern Indiana Public Service Company
Pacific Gas and Electric Company
Public Service Indiana
Sargent & Lundy
Sundstrand Corporation
Union Electric Company
Wisconsin Electric Power Company
Wisconsin Power and Light Company

This report was prepared for presentation at the Fifth Annual Review.

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1. INTRODUCTION

The electric power and energy systems area at the University of Illinois has been a significant part of the electrical engineering curriculum for well over 100 years. In the 1950's and 60's, a large portion of electrical engineering students and faculty left the power area in favor of the rapidly growing fields of communications, electronics and control. In the 1970's, the national interest in electric power systems coupled with an oversupply of engineers in other areas contributed to a substantial return of interest in the power area.

The 1980's have brought record-breaking enrollments in electrical engineering as the digital computer age matures. With reduced federal funding of research in power and energy systems, the support provided by the Power Affiliates Program is more important now than ever before. The support shows the strong interest which still endures for an active power program at the University of Illinois.

This report is a summary of the fifth-year activities directly related to the Power Affiliates Program as well as those indirectly related but perhaps stimulated by the existence of such a program. The detailed objectives and organization of the program are described in Reference [1].

2. FINANCIAL STATEMENT

The following tabulation of income and expenditures for the calendar year 1983 was prepared from a detailed University statement as of December 31, 1983, Reference [2]

Income carried over from the calendar year 1982	-\$ 8,510.00
Total income during calendar year 1983	<u>50,000.00</u>
Total available income during calendar year 1983	\$41,490.00

<u>Expenditure Item</u>	<u>Expenditure Amount</u>	<u>Percentage of Total Expenditures</u>
Graduate Assistantships	\$37,145.00	57.4
Class trips, travel	7,144.00	11.1
Communications, clerical, supplies, reports, conference fees, and administration	20,392.00	31.5
Total expenditure:	<u>\$64,681.00</u>	<u>100</u>

Summary

Amount available during calendar year 1983	\$41,490.00
Amount expended during calendar year 1983	<u>- 64,681.00</u>
Balance as of December 31, 1983	-\$23,191.00

3. THE POWER PROGRAM WITHIN THE DEPARTMENT

As of 1979, all entering electrical engineering students are required to complete 128 hours of course work for a B.S.E.E. degree. A detailed description of the undergraduate program as well as a suggested curriculum in power are given in Reference [3]. All M.S.E.E. students are required to complete a minimum of 6 units (18-24 credit hours) and complete a graduate thesis. A detailed description of the graduate program is given in Reference [4].

The Electrical and Computer Engineering Department is subdivided into eight areas as follows:

- Physical Electronics
- Atmospheric Sciences and Propagation
- Computers and Information Processing
- Electromagnetics
- Communication and Control
- Circuits and Signal Processing
- Power and Energy Systems
- Bioengineering and Acoustics

A faculty committee is assigned to each area and given the responsibility for "maintaining" that area within the department. The Power and Energy Systems Area Committee and associated faculty for the 1983-1984 academic year together with their general interests are:

J. M. Crowley (Chairman, Applied Electrostatics)
S. Ahmed-Zaid (Visiting, Machine Theory)
R. W. Burtness (Solid State Motor Drive Systems)
D. F. Hang (Engineering Economics)
M. S. Helm (Emeritus, Power System Analysis)
P. T. Krein (Visiting, Analysis and Control of Machines)
M. A. Pai (Dynamics and Control of Power Systems)
M. A. Calovic (Visiting, Analysis and Control of Power Systems)
P. V. Kokotovic (Optimization and Control of Power Systems)
P. W. Sauer (Computer Simulation of Machines and Power Systems)
M. E. VanValkenburg (Network Analysis)

A detailed summary of each faculty member's research activities is given in Reference [5].

One of the primary responsibilities of the Power and Energy Systems Area Committee is to update and staff the courses assigned to the Power and Energy Systems Area. In 1983-1984 those courses were:

EE260	Introduction to Circuit Analysis (Joint responsibility)
EE330	Electromechanics
EE331	Introduction to Electric Power Engineering
EE356	Applied Electrostatics
EE368	Solid State Motor Drive Systems
333 EE371D1	Electric Power and Energy Systems Laboratory
336 EE371D2	Advanced Electromechanical Energy Conversion I
376 EE371S1	Power System Analysis I
378 EE371S2	Power System Analysis II
EE371PE	Power Electronics

EE452 Computer Methods in Electric Network Analysis (Joint responsibility)

EE497A Advanced Electric Machine Modelling and Dynamics

EE497B Operation and Control of Power Systems

EE497C Dynamics and Stability of Power Systems

The three-hundred level courses are undergraduate courses, while the four-hundred level courses are graduate. Of these courses, EE356, EE371D2, EE497A, EE497B were not taught during the 1983-84 academic year. The Power and Energy Systems Area Committee is currently evaluating each course outline for possible revision in future semesters. A brief description of each of these courses, together with the enrollment of the past year, are included in the next section.

4. COURSES AND ENROLLMENT

As one of eight major areas in Electrical Engineering, the Power and Energy Systems Area is responsible for a considerable number of courses. The current courses assigned to the power area are described briefly below. The total annual enrollment for the 1983-1984 academic year is also given for each course.

EE260 Introduction to Circuit Analysis (Primary responsibility for this course is assigned to the circuits and signal processing area committee.)

EE260 is a three-hour course and is the first course that all electrical engineering students must take after their math, physics and computer science requirements. The course introduces elementary signal waveforms, electrical component models, basic principles of circuit analysis including d-c, transient and sinusoidal steady-state analysis. The topical outline includes R, L, C and source elements, Kirchhoff's laws, node and mesh equations, Thevenin and Norton equivalents, controlled sources, transient switching d-c analysis, and impedance and transfer functions for steady state. The course is also taken by many non-electrical engineering students. The required text was: M. E. VanValkenburg and B. K. Kinarwala, "Linear Circuits." The total enrollment for academic year 1983-1984 was 972.

EE330 Electromechanics

EE330 is an introductory course in electromechanics, presenting both the electric and magnetic quasi-static fields for analysis of energy conversion devices. The origin of forces and torques, together with the full mechanical dynamics of Newton's Second Law (NSL), are discussed. The concepts of flux linkage, energy, coenergy and the resulting induced voltages are presented for their inclusion in Kirchhoff's Voltage Law (KVL). Conservation of power and

energy is emphasized in energy balance analysis. An introduction to rotating machines is generally included as illustrative examples. Particular emphasis is given to the interaction between the electrical system (KVL) and the mechanical system (NSL). The required text is "Electromechanical Dynamics," Part I by H. H. Woodson and J. R. Melcher. This course is not required, but is in a list of three advanced three-hour EE courses of which one must be taken. The other two are probability and solid state devices. The total enrollment for the academic year 1983-1984 was 94.

EE331 Introduction to Electric Power Engineering

EE331 is an introductory three-hour course in the theory and analysis of electric machinery and power systems. The machinery analysis is limited to a presentation and manipulation of steady-state equivalent circuits. The power system analysis is limited to fundamental concepts unique to power circuits. A topical outline includes an overview of power system structure and the role of individual components, basic magnetic circuits including transformer fundamentals, elementary machine models, steady-state balanced symmetrical three-phase systems, one-line diagrams and per-unit representation of balanced symmetrical wye-connected systems, and introduction to nonlinear problems including constant power constraints. The required texts were: O. I. Elgerd, "Basic Electric Power Engineering" and R. D. Shultz and R. A. Smith, "Introduction to Electric Power Engineering." The total enrollment for the academic year 1983-1984 was 47.

EE356 Applied Electrostatics

EE356 is a comprehensive course in the theory and applications of electrostatics. Examples are selected from a wide variety of areas, including

computer peripherals, copying equipment, electric power systems, biomedical instrumentation, and smoke detectors. A topical outline includes electrostatic fields, free charge, surface charge, volume charge, corona, individual charge dynamics, behavior of charged surfaces and volumes, and high voltage generation and measurement. This course is an advanced three-hour EE elective. The current required text is "Applied Electrostatics" by J. M. Crowley.

EE368 Solid State Motor Drive Systems

The silicon controlled rectifier and the integrated circuit have opened wide the field of both d-c and a-c motor drive systems for electric automobiles, trucks, locomotives, track vehicles, off-highway vehicles and countless industrial drive systems. This course describes the general principles involved in the systems as well as the general characteristics of the various component parts of the systems including inverters, frequency converters, motors, generators and control systems. This course is an advanced EE three-hour elective. The current required text is "Solid-State D-C Motor Drives" by A. Kusko. The total enrollment for the academic year 1983-1984 (Spring offering only) was 20.

EE371D1 Electric Power and Energy Systems Laboratory

This four-hour course contains a laboratory one-credit hour component which is an elective in a list of 14 from which students select two. The laboratory component closely follows the three hour lectures. The fifteen experiments typically include power measurement, power factor correction, transformer characteristics, three-phase transformer connections, induction motor tests, induction motor torque-speed characteristics, synchronous machine tests, synchronous machine power characteristics, digital simulation of machine dynamics, over

current relay operation, an interconnected multimachine system, and a written plus oral project presentation on power and energy system topics. The required text in 1983 was Fitzgerald, Kingsley and Umans, "Electric Machinery." The total enrollment for the academic year 1983-1984 (Fall offering only) was 22.

EE371D2 Advanced Electromechanical Energy Conversion I

This three-hour course contains advanced theory and analysis of power system devices including transformers and all rotating machines. It includes the steady-state as well as dynamic analysis of unbalanced operation of three-phase transformers, induction, synchronous and DC machines. The analysis uses symmetrical components and dq transformations. Emphasis is placed on the time scale modelling of electromechanical devices and the solution of differential dynamic as well as algebraic steady-state equations. This course is an advanced EE elective.

EE371S1 Power System Analysis I

This three-hour course is the first of two courses on power-system analysis. Topics included are power system equivalents, network analysis, load flow, fault analysis, symmetrical components, unsymmetrical fault analysis, and introductions to economic dispatch and reliability. The course is designed to give the basic fundamentals of power system analysis and give preparation for the follow-on course. This course is an advanced EE elective. The required text in the academic year 1983-1984 (Fall offering only) was "Elements of Power System Analysis" by W. D. Stevenson. The enrollment was 21.

EE371S2 Power system Analysis II

This three-hour course is the second of two courses on power system analysis. Topics included are economic operation of power systems, optimal load flow

concepts, automatic generation control, relaying and protection, classical transient stability, modelling for dynamic and transient stability, and DC transmission. This course is an advanced EE elective. The required text in academic year 1983-1984 (Spring offering only) was "Electrical Power Systems, Design and Analysis" by M. E. El-Hawary. The enrollment was 16.

EE371PE Power Electronics

This three-hour course is a comprehensive treatment of power electronic devices and their use in the control of power systems. Topics included are switching matrices, existence functions, phase angle control, voltage control and pulse modulation, all converters and the high power considerations in diodes, thyristors, bipolar transistors and field effect transistors. This course is an advanced EE elective. The required text in academic year 1983-1984 (Spring offering only) was "Switching Power Converters" by Peter Wood. The enrollment was 15.

EE452 Computer Methods in Electric Circuit Analysis

EE452 is a graduate course designed for both electric power and electronics students. The course presents the fundamental computer algorithms utilized to analyze large scale circuits. Applications in both the power and electronics area are given. The course was described in a paper given as Reference [6]. The following topics are presented: Network topology and circuit equations, branch constraints and problem formulation, solution of sparse linear algebraic equations, solution of nonlinear algebraic equations, power and electronic system applications, solution of piecewise linear algebraic equations, explicit and implicit numerical integration methods, transient analysis of power and electronic circuits, sensitivity analysis and decomposition. The course texts

are "Computer Aided Analysis of Electronic Circuits" by Chua and Lin, and "Computer Techniques in Power System Analysis" by Pai. This course is a graduate 1 unit (three hour) elective. The total enrollment for academic year 1983-1984 was 13.

EE497A Advanced Electric Machine Modelling and Dynamics

EE497A is a proposed new 1 unit (three-hour) graduate course in the machines area. It has been offered once as a special topics course and is currently being proposed for permanent listing. The course includes the detailed analysis of single-phase machines, unbalanced polyphase machines, arbitrary reference frame theory, reduced order modelling by singular perturbation, operational impedances and time scales, stability of machines, and control of machines by power electronics. There is no text available at this time. Notes and journal articles are currently used to supplement lectures.

EE497B Operation and Control of Power Systems

EE497B is a proposed new 1 unit (three-hour) graduate course in the power systems area. It has been offered twice as a special topics course and is currently being proposed for permanent listing. The course includes energy control center functions, power system operating states, supervisory control and data acquisition, state estimation, on-line load flow, security assessment, economic dispatch, automatic generation control, optimal load flow, security constrained economic dispatch, multistage rescheduling and equivalents. The course typically also includes a trip to a local energy control center. There is currently no text available. Notes and journal articles supplement the lectures.

EE497C Dynamics and Stability of Power Systems

EE497C is a proposed new 1 unit (three-hour) graduate course in the power systems area. It has been offered three times as a special topics course and is currently being considered for permanent listing. The course includes the dynamic representation of interconnected power systems - electrical plus mechanical, linearized dynamic models of multimachine systems, methods of coherency identification, order reduction by singular perturbation, time scale decomposition and aggregation techniques, dynamic equivalents, direct methods of stability analysis and power system stabilizer design. The current texts available are "Power System Control and Stability" by Anderson and Fouad, "Power System Stability" by Pai, and "Time Scale Modeling of Dynamic Networks with Applications to Power Systems" edited by Chow. The total enrollment in this course during academic year 1983-1984 was 4.

Video-Taped Course Work

The graduate committee of the department is finalizing plans to offer a M.S. degree for students through video tape course credit. The details of the degree regarding the exact title and thesis requirements are currently under discussion. The power area plans to offer the three graduate 497 courses described above in the coming three semesters. The fee for these courses by video tape is normally \$2000 for tape rental plus \$300 registration fee for each student seeking graduate credit. As a consortium, two or more companies may reduce their \$2000 rental fee by sharing tapes as one entity. Further details about the courses, fees and degree credit will be supplied in the near future.

NUMBER OF POWER AREA GRADUATES FOR RECENT YEARS

1950-1970 Annual Average Power Area Graduates

B.S.E.E. - 25

M.S.E.E. - 3

1971-1980 Annual Average Power Area Graduates

B.S.E.E. - 44

M.S.E.E. - 7

1981-1982 Power Area Graduates

B.S.E.E. - 44

M.S.E.E. - 4

1982-1983 Power Area Graduates

B.S.E.E. - 33

M.S.E.E. - 5

Ph.D.E.E. - 2

1983-1984 Power Area Graduates (expected)

B.S.E.E. - 25

M.S.E.E. - 4

Ph.D.E.E. - 1

These figures do not include the significant number of graduates in related fields who have performed research in the application of control to power systems.

5. GRADUATE STUDENTS AND PROJECTS

This section of the report contains the listing of graduate students whose major research efforts were influenced directly by the Power Affiliates Program during the calendar year 1983. While not all of these students received financial aid from the Power Affiliates Program in terms of Research Assistantships, they were all associated with the program through the active involvement of their respective advisors. Those students supported by the Power Affiliates Program received maximum one-half time Research Assistantships for 11 months. The results of their work will be made available to all affiliate companies in the form of technical reports. The following students were associated with the Power Affiliates Program, and their work is described in the following pages:

Ahmed-Zaid, Said (Ph.D.)
Anderson, Kevin (M.S.)
Baranek, Mark (M.S.)
Behera, Anup (Ph.D.)
Christensen, John (Ph.D.)
Clanin, Tom (M.S.)
Kendrick, Regina (M.S.)
Khorasani, K. (Ph.D.)
LaGesse, Dale (M.S.)
Peters, Dennis (M.S.)
Seyed-Yagoobi, J. (Ph.D.)
Stupar, Mark (M.S.)
Wojciechowski, Roy (M.S.)

Name: Said Ahmed-Zaid
Date of Birth: May 5, 1956
Place of Birth: Algiers, Algeria
Received B.S.: May 1979 (U of I)
Received M.S.: December 1980
Started Ph.D.: January 1981
Advisor: P. W. Sauer/M. A. Pai/P. V. Kokotovic
Support: Partial Power Affiliates Program, Partial University of
Illinois (TA)
Research Title: "Multi-Time-Scale Modeling and Aggregation of Higher Order
Synchronous Machine Models"
Status: Project continuing (Ph.D. expected May 1984)

ABSTRACT

Aggregation in multimachine power systems with field flux decays is examined. Reduced order models describing the behavior of the slow core of the system are obtained using singular perturbation techniques. The project provides a comprehensive time scale approach to multimachine dynamics using a consistent theory with the capability for varying degrees of accuracy in reduced order modeling. The most recent results include a rigorous derivation of improved reduced order models of machines with damper windings. Preliminary results are summarized in [7] - [9].

Name: Kevin S. Anderson
Date of Birth: April 24, 1959
Place of Birth: Hinsdale, IL
Received B.S.: May 1981 (Rose Hulman)
Started M.S.: August 1981
Advisor: D. P. Looze/P. W. Sauer
Support: University of Illinois TA
Research Title: "Real Time Laboratory Control of Interconnected
Synchronous Machines"
Status: Continuing (M.S. received January 1984)

ABSTRACT

This project is a continuing effort to construct the hardware and microprocessor software for the real-time control of four interconnected synchronous machines in the machinery laboratory. In this portion of the project, speed and voltage sensing circuits were designed and built for input to an 8080 microprocessor. Errors from desired values are driven to zero through closed-loop control of the prime mover (d-c motor) and generator (synchronous machine) field circuits. The hardware and software have successfully been used to stabilize the operation of two synchronous machines when subjected to a large disturbance which were previously unstable.

Name: Mark R. Baranek
Date of Birth: August 18, 1961
Place of Birth: England
Received B.S.: June 1983 (U. of I.)
Received M.S.: August 1983
Advisor: P. W. Sauer/M. A. Pai
Support: Power Affiliates Program
Research Title: "Fast Stability Analysis"
Status: Continuing

ABSTRACT

There is a rapidly emerging need for fast stability analysis both in off-line as well as on-line operation of power systems. In this project, trajectory approximations are being used to obtain closed form expressions for energy functions as functions of time. Quadratic angle time trajectories are assumed for the fault on period and used with the post fault potential energy function to develop a time series expression for the potential energy. The potential energy boundary surface method is then being applied to obtain rapid stability results.

Name: Anup K. Behera
Date of Birth: September 24, 1958
Place of Birth: India
Received B.S.: May 1980 (I.I.T. India)
Received M.S.: May 1982 (U. of I.)
Started Ph.D.: August 1983
Advisor: P. W. Sauer/M. S. Pai
Support: Partial Power Affiliates Program
Research Title: "Energy Function Sensitivities"
Status: Continuing

ABSTRACT

Energy function sensitivities describe how stability margins are affected by system parameters such as loading or shunt var sources. These sensitivities have application in stability constrained optimal power flows, security enhancement, and on-line dynamic security assessment. This project is closely related to other projects which provide a coordinated effort to develop fast stability analysis algorithms. Initial results were presented in [10].

Name: John P. Christensen
Date of Birth: June 5, 1960
Place of Birth: Los Angeles, CA
Received B.S.: December 1981 (U. of I.)
Received M.S.: July 1983 (U. of I.)
Started Ph.D.: August 1983
Advisor: P. W. Sauer
Support: Power Affiliates Program
Research Title: "Fast Transient Stability Calculations"
Status: Continuing

ABSTRACT

In this project, the fundamental energy balance which must exist in an interconnected set of synchronous machines is being analyzed. Methods for determining critical energy transfers for stability are being considered. Piecewise linear sine function approximations are being used to obtain closed form rotor angle trajectories. A square wave approximation to the sinusoidal power transfer function is being examined for possible use in an energy transportation scheme. The idea of this approach is based on the fact that stability is maintained only if sufficient energy is transported between machines before a critical time.

Name: Thomas J. Clanin
Date of Birth: June 23, 1956
Place of Birth: Chicago, Illinois
Received B.S.: May 1979 (U. of I.)
Received M.S.: August 1983
Advisor: P. W. Sauer
Support: Construction Engineering Research Laboratory
Research Title: "Control of Fan Drives for Constant Pressure Operation"
Status: Continuing

ABSTRACT

The U.S. Army Construction Engineering Research Laboratory has developed a test facility for advanced heating and air conditioning systems. They are considering variable speed operation of an inverter fed induction motor for constant air duct pressure during normal damper operation. In this project, a microprocessor is being used to implement real-time control of the fan motor speed to obtain the constant pressure. The problem is complicated by noise in the pressure transducer output and by operation requirements to obtain rapid response when all dampers are closed.

Name: Regina L. Kendrick
Date of Birth: November 28, 1957
Place of Birth: Kennett, Missouri
Received B.S.: June 1981 (GM Inst.)
Received M.S.: August 1983
Advisor: D. P. Looze/P. W. Sauer
Support: University of Illinois TA
Research Title: "Real Time Laboratory Control of Interconnected Synchronous
Machines"
Status: Continuing (M.S. received August 1983)

ABSTRACT

This project is a continuing effort to construct the hardware and microprocessor software for the real time control of four interconnected synchronous machines in the machine laboratory. In this portion of the project, various software control algorithms are being tested for use on two interconnected machines. Mathematical models of the dynamic performance of the two d-c machines and two synchronous machines are being developed for higher level control functions. The machines were tested to determine their model parameters and compared with subsequent on-line measurement of operating quantities such as torque angles. The mathematical models predict operating characteristics to within 10% and will be used to construct stabilizing software.

Name: Khashayar Khorasani
Date of Birth: March 23, 1960
Place of Birth: Tehran, Iran
Received B.S.: May 1981 (U of I)
Received M.S.: December 1982 (U of I)
Started Ph.D.: January 1983
Advisor: M. A. Pai
Support: Power Affiliates Program
Research Title: "Modal Energy Functions"
Status: Continuing

ABSTRACT

This project was recently initiated to investigate the possible use of linear modal concepts in conjunction with recent transient energy methods for stability assessment. When transients occur in power systems, the dynamic responses can be separated into time scales which reflect slow and fast phenomena. The computation time for stability analysis can be greatly reduced if the critical information can be extracted from only the relevant time scales. Preliminary results based on the analysis of mass spring systems indicate that the dynamics can be described through the fast and slow exchange of energy. This work is currently being extended to the nonlinear power system models.

Name: Dale J. LaGesse
Date of Birth: October 12, 1960
Place of Birth: Kankakee, Illinois
Received B.S.: May 1982 (U of I)
Received M.S.: August 1983
Advisor: P. W. Sauer
Support: Power Affiliates Program
Research Title: "Network Transients in Power System Dynamics"
Status: Complete (technical report available)

ABSTRACT

The fast network transients in dynamic analysis are usually represented by the steady-state relationship $I = YE$. It has been shown in the third-order single-machine model that this representation can lead to incorrect conclusions regarding the stability of certain operating points. It has also been shown that this $I = YE$ relationship is a zero-order singularly perturbed quasi-steady-state model. As such, higher-order corrections can be applied to improve the model response. Such a correction term has been successfully applied to the single-machine problem. The result is a new third-order model for single-machine analysis without the fast network transients. This work was extended to n machines interconnected through an R-L network.

Name: Dennis C. Peters
Date of Birth: June 1, 1961
Place of Birth: Staunton, Illinois
Received B.S.: June 1983 (U. of I.)
Started M.S.: August 1983
Advisor: P. W. Sauer
Support: Power Affiliates Program
Research Title: "State Estimation of Transformer Taps in Looped Systems"
Status: Terminated (D. C. Peters left the U. of I.)

ABSTRACT

In this project, state estimation algorithms were being evaluated to estimate tap changing under load tap positions when two or more devices were included in a network loop. Current algorithms have generally failed in this configuration.

Name: S. J. A. Seyed-Yagoobi
Date of Birth: December 28, 1954
Place of Birth: Tehran, Iran
Received B.S.: May 1978 (Aryamehr Tech)
Received M.S.: May 1981 (U of I) (Mechanical Engineering)
Started Ph.D.: June 1981 (Mechanical Engineering)
Advisor: P. T. Krein
Support: Partial Power Affiliates Program
Research Title: "Effects of Long-Term Low Level Corona Discharge on
Liquid Dielectrics
Status: Completed

ABSTRACT

The strong electric fields in power equipment, such as underground cable systems and transformers, can be used to pump the insulating oils in these devices by a process called "Electrohydrodynamic Pumping".[11] This pumping requires both a strong field and a bulk charge in the liquid to be pumped. In many devices, the temperature gradients create non-uniform fields which cause bulk charge to be present in the liquid. For improved pumping, it is helpful to provide additional charge by corona charge injection. The purpose of this study is to determine whether or not the low levels of corona will degrade the electrical insulating properties of the oils. The experimental setup consists of 16 one-liter beakers of oil, eight with Sun #4 and eight with Chevron D-100. Eight beakers are used as control samples while the other eight contain single edge razor blades. Conductivity and permittivity are measured periodically with a Harris low-frequency bridge. Early results show that low levels of corona do not affect permittivities and that effects on conductivity are minimal.

Name: Mark Stupar
Date of Birth: November 9, 1949
Place of Birth: Springfield, Illinois
Received B.S.: January 1972 (U. of I.)
Started M.S.: August 1983
Advisor: M. A. Pai
Support: University of Illinois
Research Title: "Multiple Time Scale Modeling of Synchronous Machines"
Status: Continuing

ABSTRACT

The mathematical model of a single synchronous machine can be shown to exhibit at least three distinct time scales. These models are being analyzed to obtain improved reduced order models in each of the three time scales. These are the stator transients (fast), the mechanical dynamics (medium) and the field transients (slow). The project will also consider additional time scales to include damper winding models.

Name: Roy Wojciechowski
Date of Birth: September 9, 1961
Place of Birth: La Salle, Illinois
Received B.S.: June 1983
Started M.S.: August 1983
Advisor: Computer Engineering Area (hourly Power Affiliates Program)
Support: University of Illinois (Teaching Assistant)
Research Title: Under development
Status: Continuing

ABSTRACT

This abstract does not address the M.S. research of Mr. Wojciechowski, rather it summarizes a special project which he has been undertaking for the power group. A digital torque angle meter is being developed. This was originally initiated with Dennis Peters in 1983 but was transferred to Roy since his specialty is digital circuits. The meter obtains a rotor position pulse from an optical coupler and a stator voltage zero crossing pulse from a sensing transformer. The digital circuit computes the time between pulses and converts that time into an angle display.

6. UNDERGRADUATE PROJECTS

While the majority of research projects funded through the Power Affiliates Program are oriented towards graduate students, a substantial effort is made to interest undergraduate students in the challenges of the power area. In many cases, juniors and seniors select special projects which supplement their required coursework. These projects often involve considerable time and effort of both the students and faculty. Funds are used to purchase small pieces of equipment and provide hourly income to summer students. During the past year, the following major undergraduate projects were initiated:

A Model Power System for Laboratory Experiments

This continuing project is supervised by Prof. Krein and included efforts by a number of students, including Randy Sparks and Ken Riches. The goal of this project is to develop a realistic system to allow laboratory work in power system analysis, operation, and control. An eight-bus three-machine system rated at 30 kVA has been built and used as a demonstration in the existing laboratory course. A commercial speed controller (Cutler Hammer) provides speed control for one of the three shunt d-c motors which serve as prime movers. A locally designed pulse-width-modulated d-c converter is available to provide automatic voltage control, and will eventually serve as an electronic speed control.

The power laboratory Apple IIe computer system (Furnished by General Electric Co.) is currently being prepared to serve as a SCADA device for the system. Software for load flows, system modifications, and graphic display have been written and tested. Hardware and software for direct computer control of relays have been successfully demonstrated. Efforts on data acquisition and other aspects are continuing.

Expected Value of Asymmetrical Fault Current

This project was supervised jointly by Prof. Sauer and Mr. Russell Stoss (Illinois Power Co.) and was conducted by Tracy Bauer. The asymmetrical fault current in an R-L circuit is a function of the switching instant. In this project, the switching instant was considered a random variable of uniform distribution. As such, the d-c component and thus the first-cycle RMS current are random quantities with nonuniform distributions. A Monte Carlo study of the statistics was made and was reported in a student paper contest at the 1984 IEEE PES Winter Meeting. The paper was judged an "outstanding paper."

Universal Robot

This project is being supervised by Prof. Sauer and is being conducted by eight minority students. The robot is powered by combinations of d-c and stepper motors. The motion is remotely-controlled by command stick and terminal board for interface control by an IBM donated microprocessor. The robot is in its initial stage of construction and will be modified by future students. The complications of multidiscipline technology offer the students a significant challenge.

Large Scale System Software

The entire system planning software package used by Philadelphia Electric Co. has been obtained for use by the power area. The package has been loaded onto the University of Illinois Cyber computing system. Since the P.E.C.O. programs are written for use on an IBM machine, they must be modified to be usable on the CDC machine. This project will involve several students and will continue for some time. When operational, the programs will be useful in both teaching and research. The programs can simulate virtually any modern day interconnected power system using conventional modeling techniques.

7. ACTIVITIES

The following chronological listing of 1983 events and highlights is a brief outline of the direct and indirect influence of the Power Affiliates Program on the University of Illinois and Industrial Affiliates.

January

- C. A. Wegner and F. A. Luedtke complete M.S.
- Spring Semester began with eight power courses offered and taught.
- Milan Calovic arrives for one semester visiting appointment.
- Mark Stupar begins M.S.

February

- I.E.E.E. PES Winter Meeting attended by M. S. Helm and P. W. Sauer. Pete Sauer presented a paper.
- Power area graduate listing mailed to companies.
- Sundstrand \$5000 support of power electronics.
- David Hill visits and presents a seminar on stability assessment.

March

- Electrical Engineering Open House held with displays of power projects and machinery demonstrations.
- Sargent and Lundy Faculty Engineering Conference attended by M. S. Helm, P. W. Sauer, and D. F. Hang.
- Milan Calovic presents a seminar on Automatic Generation Control (AGC).

April

- American Power Conference attended by the following faculty and students with sponsors:

M. S. Helm (A.P.C.)	D. J. Eriksen (C.E.)
P. W. Sauer (U.E.)	R. E. Gyenes (C.E.)
M. A. Pai (C.E.)	M. L. Martina (I.P.)
P. T. Krein (Brown & Root)	T. S. Koertge (I.P.)
R. J. Mosborg (S.L.)	J. E. Davis (S.L.)
J. E. Peters (C.E.)	W. A. Kania (S.L.)
C. S. Larson (C.I.P.S.)	W. C. Alt (W.P.L.)
C. A. Volkmann (Brown & Root)	T. A. Hetzler (C.I.L.C.)

- Said Ahmed Zaid presents seminar on Aggregation.

May

- Fourth Annual Review of the Power Affiliates Program
- P. W. Sauer, J. P. Christensen, S. Ahmed-Zaid attend the 1983 Int. Symp. on Circuits and Systems, John and Said present papers. Pete Sauer visits EPRI and presents a seminar at U. C. Berkeley.
- M. Calovic and P. W. Sauer attend the 1983 Power Industry Computer Applications Conference. Pete Sauer presents a paper.
- Dennis Peters and Pete Sauer attend the 1983 Power Industry Division meeting of the Instrument Society of America. Porter Womeldorff (I.P.) receives achievement award which also includes a \$2000 scholarship to Dennis Peters. Dennis presents a paper as the student awardee.
- J. P. Christensen completes M.S.
- Spring Semester closes with 21 B.S. and 3 M.S. graduates in Power.
- J. P. Christensen begins Ph.D.

June

- M. A. Pai attends 1983 American Control Conference and presents a paper.
- Milan Calovic presents seminar on Decentralized AGC.

July

- IEEE PES Summer Power Meeting attended by M. S. Helm, and P. W. Sauer. Pete Sauer presented a paper.
- F. M. A. Salam visits and presents seminar on Chaos and Arnold Diffusion.

August

- Power graduate listing mailed to recruiting companies.
- Fall semester begins with six courses offered and taught.
- Mark Baranek and Dennis Peters begin M.S.
- K. Khorasani presents seminar on decentralized energy functions.

September

- Pacific Gas and Electric - \$1000 contribution to power affiliates program.
- Said Ahmed-Zaid presents seminar on field flux aggregation.

October

- Machinery lab students and graduate students visit the Commonwealth Edison Control Centers, accompanied by P. W. Sauer.
- Phil Krein presents seminar on Power Electronics.

November

- M. S. Helm, P. W. Sauer, M. R. Baranek and J. P. Christensen attended the Midwest Power Symposium. John Christensen and Pete Sauer presented papers.
- General Electric - \$5000 contribution for machine lab control equipment.

December

- Fall semester closes with 7 B.S., 1 M.S. and 1 Ph.D. graduates in power.
- S. Ahmed-Zaid completes Ph.D. requirements.
- Amoco - \$5000 contribution for power program.

8. LABORATORY FACILITIES

Virtually all of the University of Illinois laboratories are available to students studying in the power and energy systems area of Electrical Engineering. The electric machinery laboratory is located on the ground floor of the Electrical Engineering Building. It is primarily an instructional laboratory capable of accommodating classes of 12 with potential to expand to classes of 24. Although much of the equipment is at least 20 years old, it is sufficient and plentiful for introductory undergraduate instruction in rotating machinery, transformers, harmonic waveforms, elementary system concepts, and other power fundamentals. The laboratory is being equipped for real-time monitoring and control of four interconnected machines and loads. The small model power system is used for undergraduate instruction and has the potential for use in graduate research in the control of interconnected machines.

The high-voltage laboratory was dismantled some time ago, and converted into the current bioengineering laboratory. While there has been some interest recently in high-voltage phenomenon by both undergraduate and graduate students, there are no current plans to revitalize the high-voltage lab. The electric machinery laboratory students have in the past taken field trips to Kearney Corporation in Chicago to observe actual high-voltage testing procedure and demonstrations.

Perhaps the most widely used laboratory for both education and research is the Digital Computer Laboratory of the University of Illinois. Two Control Data Corporation CYBER 175's are available through a remote job site on the first floor of the Electrical Engineering Building. The Electrical Engineering remote job site is controlled by a PDP 11 computer to support a card reader, high-speed line printer and 23 remote interactive time-sharing terminals. The use of the

digital computer has been integrated into virtually all of the power courses. The facilities are also used extensively by the members of the power and energy systems area faculty and their graduate students in research efforts. The facilities are very useful in the development of interactive programs. The DEC 10 computer located in the Coordinated Science Laboratory is also available for graduate research. The PLATO system, which was initially created by the Computer Science Department, is used extensively in many areas of the undergraduate curriculum.

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